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흉부 디지털토모영상의 기본모드 및 부가여과사용 시 환자선량과 화질비교

Digital Tomosynthesis Imaging of the Chest : Comparison of Patient Exposure Dose and Image Quality between Default Setting and Use Additional Filter

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요약

흉부 디지털토모장치는 가장 발달한 촬영방법중의 하나이지만 일반 흉부촬영방법에 비해 환자의 피폭선량이 높다는 단점이 있다. 이런 이유 때문에 본 연구는 흉부 디지털토모영상에서 부가여과를 사용하여 환자선량을 저감시키는 방법을 검토하여 보았으며, 화질의 변화도 실험하였다. 그 결과 부가여과가 없는 장치의 기본상태에서 피부입사선량, 면적선량, 실효선량은 1.95 mGy, 17.66 dGycm^2, 0.133 mSv로, 부가여과사용 시는 0.312 mGy, 2.27 dGy.cm^2, 0.052 mSv로 나타나 선량이 각 각 66.2%, 73.6%, 57.4%로 감소하였다. 화질에서 병소의 검출율은 중심부 미소병소 검출율($p < .001$)을 제외한 나머지 주변부, 중심부병변 및 주변부 미소병소에서는 두 방법에서 큰 차이를 보이지 않았으며, 환자의 선량감소에는 큰 효과를 볼 수 있었다.

■ 중심어 : | 부가여과 | 흉부촬영 | 디지털단층검사 | 환자선량 |

Abstract

Chest digital tomosynthesis was the most advanced digital radiography technology, but it was higher patient dose than conventional chest radiography. Thus we tried to reduce a patient dose of chest digital tomosynthesis and evaluated its image quality. Result shows that radiation dose such as ESD, DAP and ED were 1.95 mGy, 17.66 dGycm^2 and 0.133 mSv respectively in default setting and 0.312 mGy, 2.27 dGy.cm^2 and 0.052 mSv in use additional filter, respectively. Doses were decrease 66.2%, 73.6% and 57.4% in ESD, DAP and ED, respectively. At the image quality assessment, overall sensitivities of use additional filter for nodule detection were not inferior to default mode for peripheral, central and peripheral micro nodules. However, sensitivity of low dose mode was significantly inferior to the default for central micro-nodules($p < .001$).

■ keyword : | Additional Filter | Chest Radiography | Digital Tomosynthesis | Patient Dose |

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Ⅰ. INTRODUCTION

Chest radiography was one of most commonly used examination method which can obtain an image with low dose within a short time and its method and procedure are somewhat simple. However, as it cannot identify the depth of lesion and it is difficult to evaluate because the chest structures are overlapped in a two dimensional flat image, sometimes, it is missed or confused during the examination when diagnosing the small lesion.

To complement such weak point, an examination method called as Digital Tomosynthesis(DTS) exists to be helpful in improving detection of subtle lesions as one of advanced digital radiography technology methods[1]. DTS removes overlapping structures using vertically shifting X-ray tube and advanced reconstruction algorithm and enhances the conspicuity of structures in the different slices. Therefore, it is advantageous in examination because it give more information than the chest radiography.

It is also noticeable in the points that it can obtain information about the shape and depth of structure, out of slice looks blurred and only structures within visual slice looks clear. DTS is a method that provides some of the tomographic benefits of computed tomography(CT) but at less dose and cost, and with an approach that is easily implemented in conjunction with chest radiography[1][2]. However, long exposure time and large number of acquisition in DTS examination would have more patient dose than the chest radiography.

It is possible that the radiation dose for the tomosynthesis examination can be reduced, since it-because of its recent introduction – has not had the same chance for optimization as radiography[3]. Thus, we made a hypothesis that we can reduce the patient dose while maintaining the image quality by changing various examination conditions when examining the chest DTS.

Thus, the purpose of this study was to find dose reduction setting to reduce the patient dose in DTS examination and compare the image quality between the default setting.

Ⅱ. METHODS AND MATERIALS

1. Scan Methods

DTS was performed with a commercial CsI/a – Si – panel detector system (Definium 8000, Volume RAD, GE Healthcare, Milwaukee, WI). Chest volume in RAD examination that moves tube angle from +15 to -15 and the number of acquisition (exposure number) was 60 and scan time was 11.33 sec. Under Automatic exposure control(AEC) with the detector speed of 400.

RANDO phantom (Female alderson radiation therapy phantom, 155 cm, 50 kg, female) was used for simulation of a standard patient at the various X-ray units, for measurement of entrance surface dose(ESD), the dose area product(DAP), and effective dose(ED). It simulates the attenuation and scatter characteristics in the lung-field region of an average patient, for X-ray used in chest radiography.

Lung/chest Phantom (developed in conjunction with the University at California, Irvine's Department of Radiological Sciences) was used for evaluation of the image quality.

Glass dosimeter(Dose ACE, Asahi technology Co.) and GD-352M component was used as well to measure ESD.

2. Dose Measurements

To obtain absorbed Dose necessary for ED calculation, inserted glass dosimeter into several internal organs of RANDO phantom and attached three of glass dosimeters on the center at thoracic vertebrae 4 level (both lung, vertebral of surface). The attachment location of glass dosimeters was maintained same for all the measurement.

And position the prepared RANDO Phantom closely to the front of detector with posterior-anterior position.

Tube voltages, copper filter thickness, and dose ratio were changed to the followings and exposed, and recorded ESD, DAP displayed on the equipment from each combination.

And decided the condition which has lowest ESD and DAP value among the above combination as low dose Setting(LD mode, use additional filter).

And we obtained Absorbed dose by glass dosimeter from original default setting(High dose setting) and LD setting and obtained the effective dose[Sv] from the following equation.

Effective dose[Sv] = Absorbed dose × Equivalent dose × Tissue weighting factor (1)

3. EVALUATE THE IMAGE QUALITY

To evaluate the image quality, take out the lung model and diaphragm inserted into lung/chest Phantom and made and fixed 3 set of artificial nodules phantom inside.

We cut the Styrofoam fit to the internal size of phantom and attached randomly total 20 grains of soaked adlay, red-bean, millet and un-soaked millet, 5 grains each, on one of Styrofoam and made 3 sets of artificial nodules.

Also, inserted 3 sets of artificial nodules into the inside of phantom and attached 20 artificial nodules randomly on the surface(lower lung, vertebral region) of model which looks like diaphragm to support the model such as original lung to insert into phantom.

With this, total 80 artificial nodules were inserted into the phantom which comprise 40 nodules with 4~8 mm of diameter and micro-nodules with less than 4 mm.

Also, the distributed numbers of over 4 mm nodules and micro-nodules in the overlapping region with the spine or peripheral region which is lung field area having no overlapping with central region behind Thoracic diaphragm were counted in advance.

After exposing these phantoms under the conditions of LD Setting and default setting, we could obtain 2 folders of DTS image.

From those images, 4 readers counted the number of over 4 mm nodules and micro nodules detected in the central region and peripheral region.

One reader was board-certified radiologist with 15 years of experience in chest radiology. The two readers were board-certified radiologist with two-years of experience. And one other was fourth-year radiology resident.

To maintain the objectivity of image reading, they were evaluated in the same space and fixed time independently.

4. STATISTICAL ANALYSIS

We checked the significance in the numbers of nodule and sensitivities detected under the four conditions combined differently by size and region like central micro nodules, peripheral micro nodules, central nodules and peripheral nodules using ANOVA analysis in LD setting and default setting. (SPSS 1.2K used)

Ⅲ. RESULTS

1. Dose Measurement

The followings are the values of ESD and DAP measured according to the changes of kVp, Cu filter and dose ratio.

First, comparison of measurement of ESD and DAP according to the change of dose ratio. We have tested setting dose ratio as 1:10(default) and 1:5. When the test was performed with 1:5 ratio at 120 kVp, the values of DAD and ESD were decreased by 51.36% and 52.82% respectively compared with

Table 1. Dose measurement

Tube voltage (kVp)	Dose ratio	additional filter(mm)	TOMO	
			ESD (mGy)	DAP (dGy·cm^2)
120	1:10	No	1.95	17.66
		Cu 0.3	0.60	4.77
	1:5	No	0.92	8.59
		Cu 0.3	0.38	2.97
100	1:10	No	1.25	10.66
		Cu 0.3	0.58	4.61
	1:5	No	0.67	5.11
		Cu 0.3	0.31	2.27
80	1:10	No	1.27	11.07
		Cu 0.3	0.73	5.66
	1:5	No	0.69	5.37
		Cu 0.3	0.37	2.89

1:10 ratio and at 100 kVp and 80 kVp, the value of DAP was decreased by 52.06% and 51.49% respectively and the value of ESD was decreased by 46.4% and 45.67% respectively.

Second, Compared by the use of Cu filter, the measured values of DAP and ESD at 120 kVp in dose rate 1:10 were decreased 72.99% and 69.08% respectively and at 100 kVp and 80 kVp, the value of DAP was decreased by 56.75% and 48.87%, the value of ESD was decreased 53.6% and 42,52% respectively.

Also, in case of dose ratio 1:5, the values of DAP and ESD at 120 kVp were decreased by 65.42% and 58.7% and at 100 kVp and 80 kVp, the value of DAP was decreased by 55.58% and 46.18%, the value of ESD were by 53.73% and 46.38% respectively.

Finally, looking at the dose change according to the change of kVp when the Cu filer was used or not (dose ratio fixed at 1:5) at tube voltage from 120 kVp to 100 kVp, the value of DAP was decreased by 23.57% and 40.51% and the value of ESD was decreased by 18.4% and 27.1% respectively.

On the other hand, the dose at low tube voltage (80 kVp) showed higher than that at 100 kVp. Finally, among three tube voltages, 100 kVp showed the lowest dose.

Therefore, we have decided the condition with the lowest dose (100 kVp, dose ratio 1:5, Cu filter 0.3 mm) as LD setting and measured each effective dose compared with default setting (120 kVp, dose ratio 1:10, no additional filter).

As the result, ED value of default setting was 0.133 mSv and the value of LD setting was decreased by 60.39% to 0.052 mSv. The biggest decrease gap was 66.7% and 60.9% showed on the skin and lung respectively among the major internal organs measured in the chest field respectively[Fig. 1].

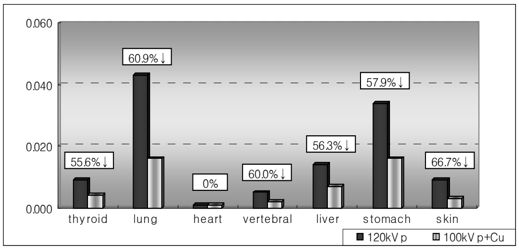

Fig. 1 Comparison of effective dose by region in default and LD setting

2. IMAGE QUALITY RESULT

The followings are the average numbers and sensitivity of micro nodules and nodules with over 4 mm diameter which were detected in central region and peripheral region at default and LD setting[Table 2].

Table 2. Mean number and sensitivity of nodule detected by region in default and LD setting

Nodule size	Region	No	Default		LD		Default vs. LD
			Mean No	Sensitivity(%)	Mean No	Sensitivity(%)	Sig. (p)
Micro nodule	P	22	17.2	78	16.9	78	0.747
	C	18	14.2	79	6.6	36	0.001
Nodule	P	24	22.1	92	22.2	93	0.842
	C	16	14.9	93	14.4	90	0.312

* Micro nodule(〈4 mm), Nodule(≥ 4 mm)
* P – Peripheral, C – Central

In case of nodules with over 4 mm, there were no statistical significance in both central region and peripheral region. (p=.842 for peripheral region, p=.312 for centralregion).

Also, in case of micro nodules, showed statistical significance between default and LD setting in peripheral region (p=.747), but showed significance in both two conditions of average number of nodules and sensitivity detected in the centralregion (p<.001)[table 2].

Ⅳ. DISCUSSION

It is often required to make additional examination or miss lesion because the anatomical structures are overlapped on the chest radiography image. But, digital tomosynthesis (DTS) has the potential to improve chest imaging by rendering slice images that can distinguish subtle structures from overlying anatomy[4]. Also, the usefulness of chest DTS method for effective lung pulmonary nodule detection was covered in various articles for last couple of years[1][3][5][6].

James T. Dobbins's study showed significant improvement in sensitivity compared to posterior anterior projection(PA) radiography[6] through 70% detection of 3~20 mm nodules with DTS examination rather than 22% detection by chest PA. Also, from the study of Jenny Vikgren for the detection of pulmonary nodules, the performance of chest DTS is better, with increased sensitivity for nodules smaller than 9 mm than chest radiography[3].

However, DTS has limitation that it has more dose than chest PA radiography.

In the study of John M. Sabol[7][8] from GE healthcare where Definium 8000 was used, ESD was 0.088 mGy and ED was 0.014 mSv in chest PA examination while ESD was 0.786 mGy and ED was 0.124 mSv in DTS examination showing increased patient dose by almost 9 times.

Even these values were insignificant compared to those of CT or high dose medical imaging examination, it would be necessary to control the dose in order to compete with the equivalent exposure condition to plain posterior-anterior chest radiography under conventional clinical environment. Therefore, in this study, we have tried to find out the method to reduce the patient dose in DTS to that of chest PA. As a result, average DAP and ESD at three tube voltages were reduced by 49.7% and 48.3% respectively at dose ration 1:5 compared to doses ration 1:10 and when Cu filter was used (dose ratio was fixed at 1:5), DAP and ESD were decreased by 49.7% and 52.9% each.

In the study of Okka W. Hamer where chest radiographic image quality were maintained equivalent and 0.3 mm copper filtration were added at 125 kVp, we have found that the patient radiation was reduced by 31%[8]. This reduction in exposure will likely become increasingly important as advanced applications such as DTS become widely available[7].

When Cu filter was used, the dose was dramatically reduced at 120 kVp rather than at 80 kVp or 100 kVp. This was because Cu, higher atomic number material, is more effective to remove photon of high energy (100 kV ~ 200 kV). Also, the dose at 100 kVp was the lowest when changed kVp. Compared with 120 kVp, DAP and ESD were averagely reduced by 32% and 38.7% respectively. This LD setting condition acquired were reduced by 57.4% compared with ED of default setting (120 kVp, dose ration 1:10, no additional filter).

ED is the dose measured for entire body. But, the ED value of internal organ such as gonad gland and bladder were not measured in this study, considering the result of SH. Park's study from Han-Yang University(Korea) that internal organs positioned out of the inside of beam will receive ignorable level of dose[9].

There was no significant difference in nodules over 4 mm under default and LD setting condition in the evaluation of image quality. But, the nodules less than 4 mm showed the lowered detection capability at LD with insufficient dose in the thick area behind Thoracic diaphragm. However, the nodules which were invisible in chest PA radiography was well observed in peripheral region and we think that the region of lung field in peripheral region will be sufficiently observed at LD setting in the clinic. Therefore, it would be proper to use default setting for the cancer patient (checking metastatic lesion of chest, first medical examination and screening) who requires detection capability of lesion rather than the difference in exposure dose but, in case that the exposure should be positively reduced such as screening for asymptomatic health body, pediatrics, young age or menace age, LD setting would be sufficient.

We thing that DTS examination easily applicable to various patients, as described above, would be useful examination as it can obtain various information such as depth and shape differently from the conventional plat radiography.

Further, it has potential to reduce the patient dose as it can control various parameter values such as dose ratio, sweep angle, kVp, filtration, speed and etc.

The conclusion of this study could reduce dose of chest DTS comparable to the conventional chest radiograph. This low dose DTS was comparable to the DTS with default dose setting for detecting lung nodules bigger than 4 mm in diameter

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